Best use of unlicensed spectrum

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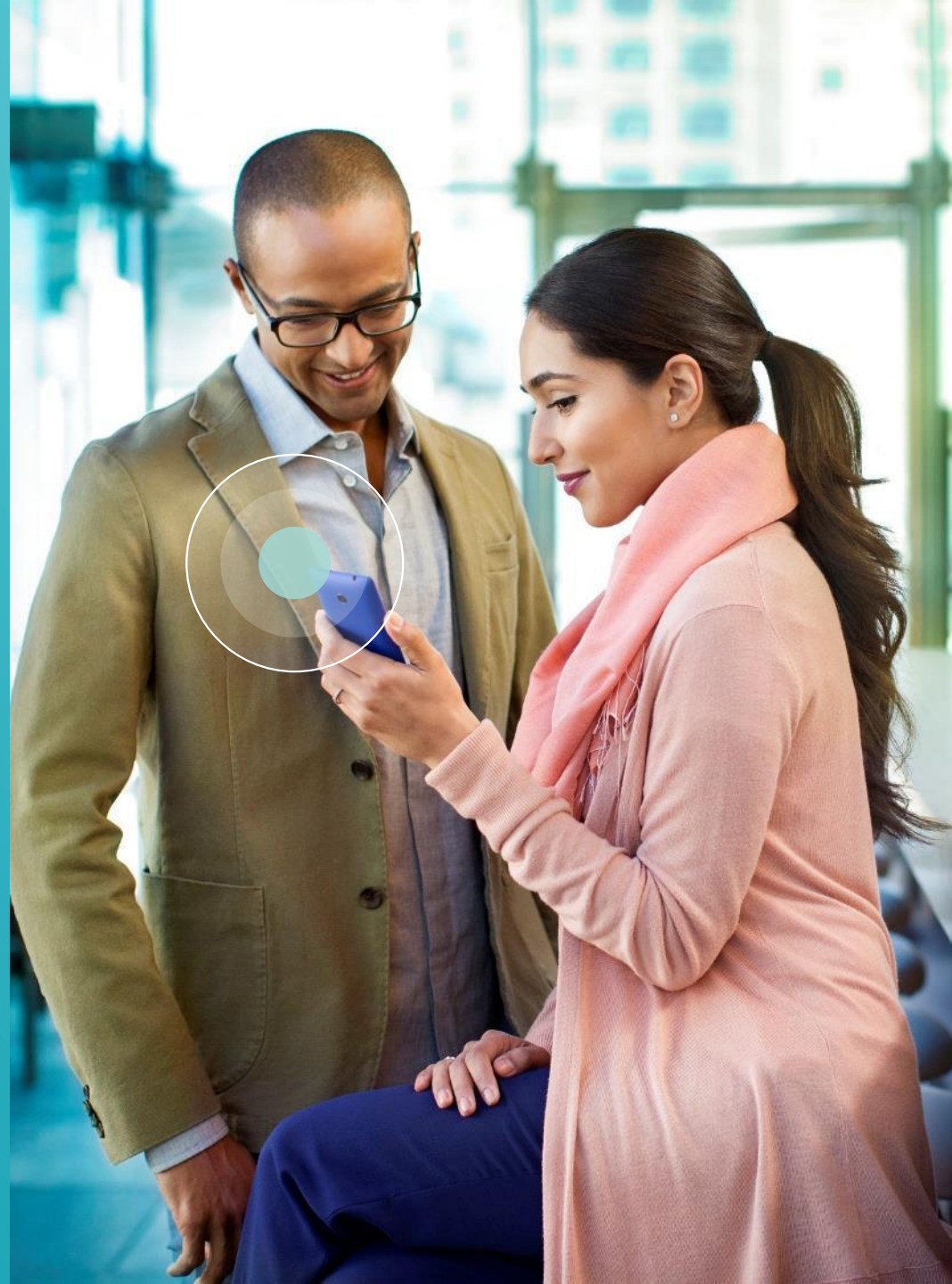
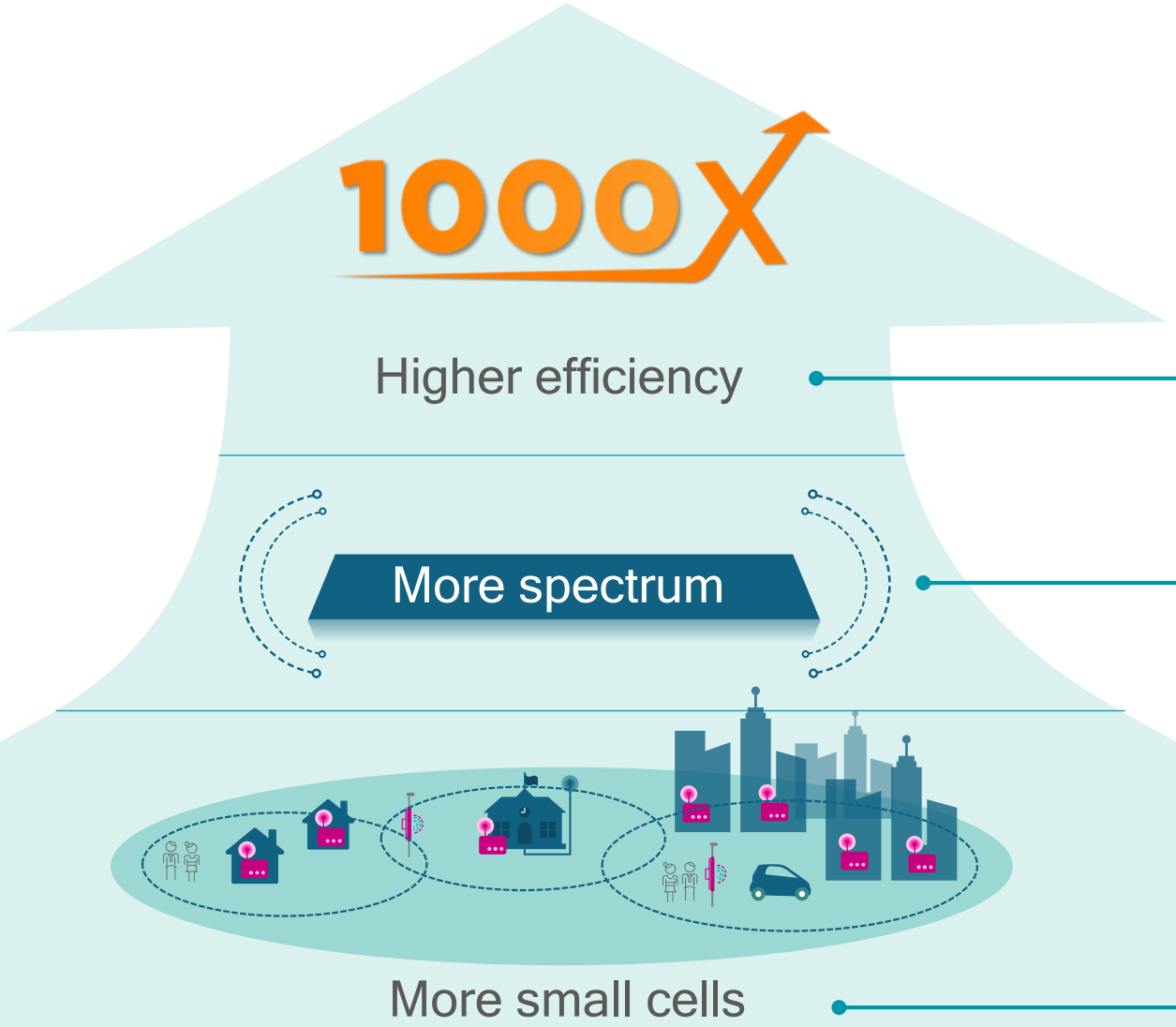
Agenda

- Overview
- LAA / LTE-U
- Wi-Fi & LWA
- LAA trial
- MulteFire™



Making the best use of licensed and unlicensed spectrum



For both licensed & unlicensed spectrum

More licensed spectrum is the top priority
Use unlicensed spectrum opportunistically

Technologies for hyper-densification

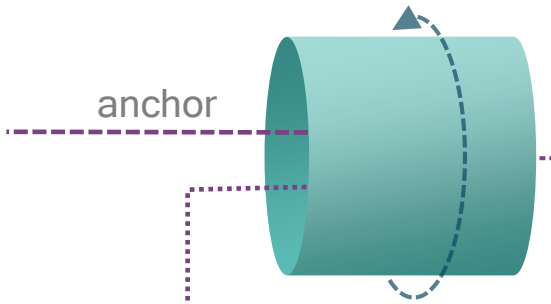
Multiple technologies will co-exist for different needs

Licensed Spectrum

Exclusive use

Unlicensed Spectrum

Shared use



Aggregation with licensed anchor channel

LTE-U / LAA (Licensed-Assisted Access)

Targeting mobile operators using LTE in unlicensed spectrum for new small cell deployments

LWA (LTE Wi-Fi Link Aggregation)

Targeting mobile operators leveraging existing carrier Wi-Fi deployments

MulteFire

Broadens LTE ecosystem to enhanced and new deployment opportunities

Wi-Fi (11ac/11ad/11ax/11ay)

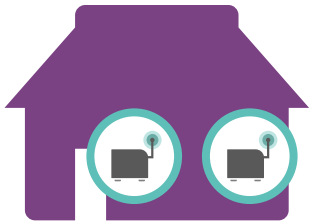
Evolving for enhanced performance and expanding to new usage models

Making best use of 5 GHz unlicensed band

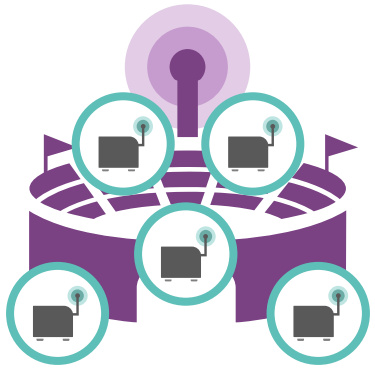
LTE-U/LAA, LWA, MulteFire and 802.11 ac/ax will coexist in 5 GHz

Enterprises

Small Businesses



Venues



Residential/ Neighborhood

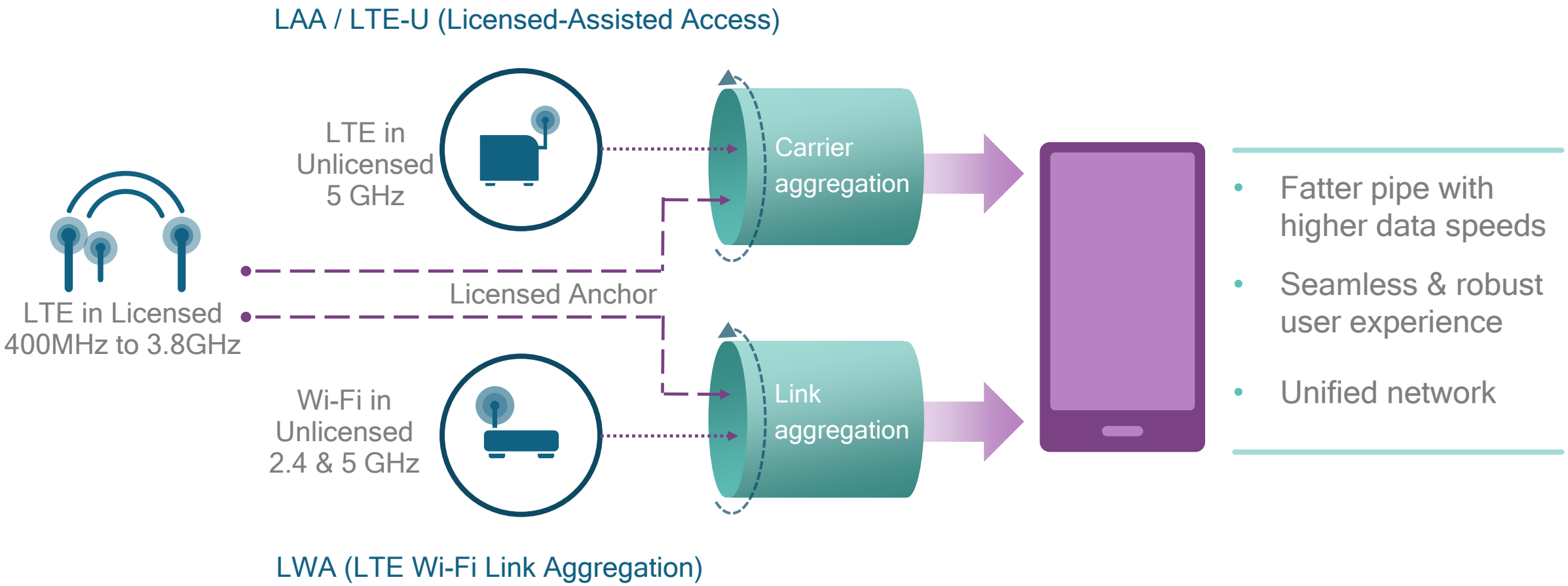
Large amounts of spectrum available globally (~500 MHz[1])

Ideal for small cells thanks to lower mandated transmit power

Global neutral spectrum that can serve any user with same deployment – neutral hosts

1 Regionally dependent

Aggregation with licensed anchor for best performance



- Fatter pipe with higher data speeds
- Seamless & robust user experience
- Unified network

LTE Unlicensed developed through industry collaboration

Collaboration with organizations such as Wi-Fi Alliance and IEEE

LTE-U Forum

LTE-U Forum

An industry forum defining coexistence specs **LTE-U** based on 3GPP rel. 12, for early time to market for certain markets (e.g., USA, Korea, India).

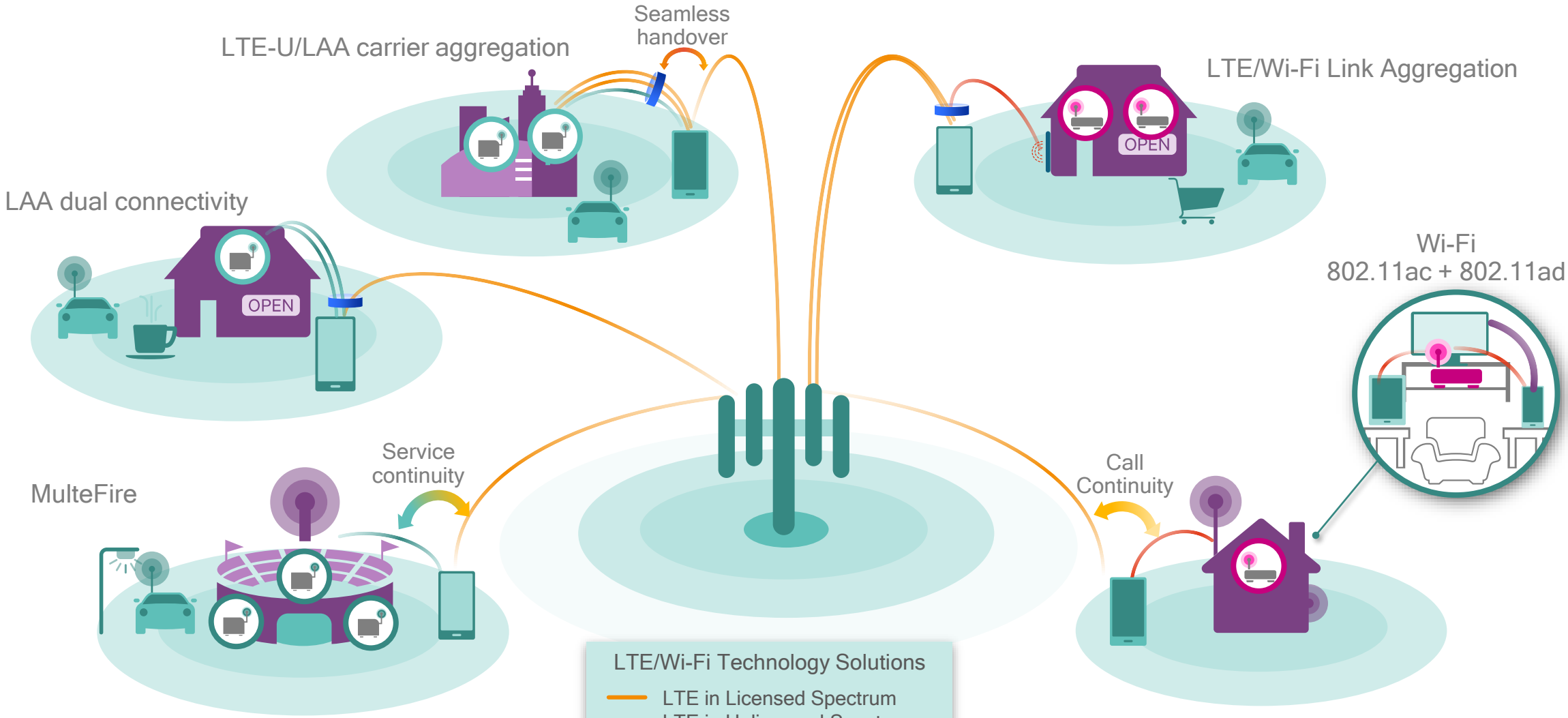
3GPP for LAA

A global standardization organization for cellular network technologies such as LTE, including **LWA** and **LAA** (rel. 13) used for aggregation of unlicensed and licensed spectrum.

MulteFire Alliance

An international association formed in 2015 that will develop global technical specifications and product certification for **MulteFire** based on 3GPP standards.

Multiple technologies for multiple deployment scenarios



LTE Unlicensed Solutions

Wi-Fi Solutions

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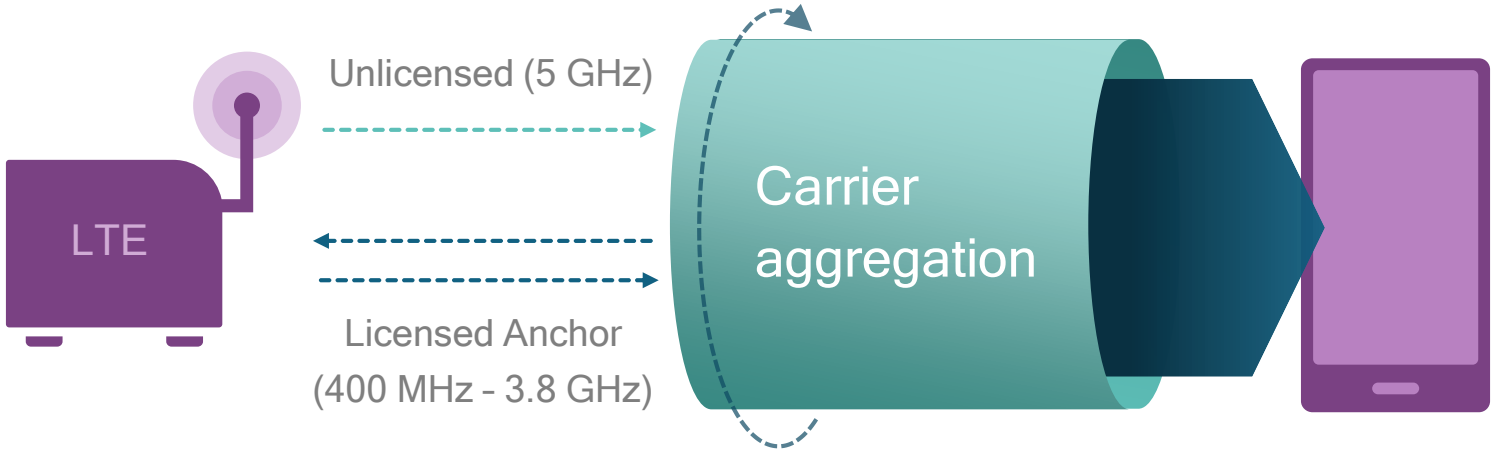
- MulteFire

Extending LTE to unlicensed spectrum

LTE-U and Licensed Assisted Access (LAA)



Supplemental Downlink (SDL) to boost downlink[1]

- **Path to Gbps speeds**
  By aggregating licensed and unlicensed
- **Seamless and robust user experience**
  With reliable licensed spectrum anchor
- **2x capacity and range**
  Over Wi-Fi capacity in dense deployments[2]
- **Single unified LTE network**
  Common management
- **Fair Wi-Fi coexistence**
  Fundamental design principle

[1] Aggregating with either licensed TDD or licensed FDD is possible with SDL; [2] Assumptions: 3GPP LAA evaluation model based on TR 36.889, two operators, 4 small-cells per operator per macro cell, outdoor, 40 users on same 20 MHz channel in 5 GHz, both uplink and downlink in 5 GHz, 3GPP Bursty traffic model 3 with 1MB file, LWA using 802.11ac, DL 2x2 MIMO (no MU-MIMO), 24dBm + 3dBi Tx power in 5 GHz for LAA eNB or Wi-Fi AP.

LTE-U and LAA part of the same evolution

LTE-U

Time to market for certain regions: USA, Korea, India

Based on 3GPP R12

- Supplemental downlink (SDL) to boost downlink
- Dynamic channel selection to avoid Wi-Fi and adaptive duty cycle (CSAT) to fairly coexist
- Support for migration to LAA

LAA

Includes LBT required for global deployments

3GPP R13

- Supplemental downlink (SDL)
- Dynamic channel selection
- Listen before talk (LBT) complying with global regulations

eLAA and beyond

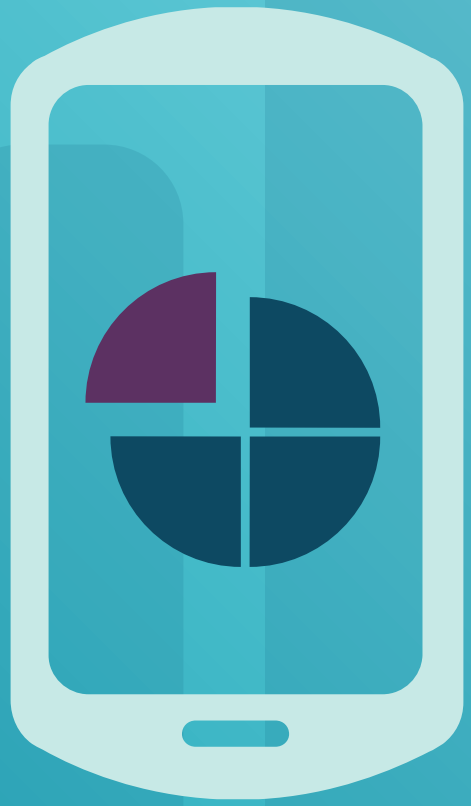
Enhancements to LAA

3GPP R14 and beyond[1]

- Adds uplink aggregation: Boost uplink data rates and capacity[2]
- Dual Connectivity: Aggregation across non-collocated nodes
- Complexity reduction[3]

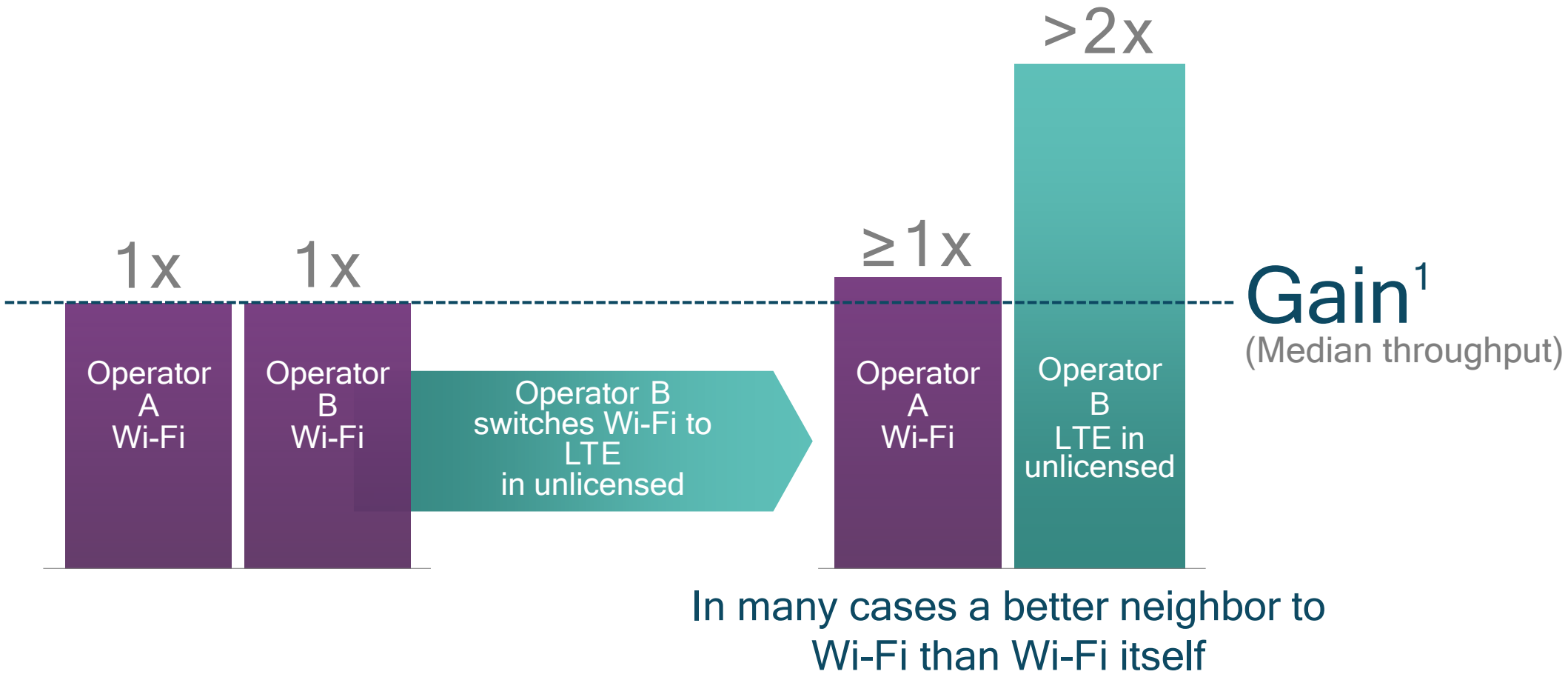
[1] UL aggregation part of Rel. 14–other features proposed; [2] Aggregation of unlicensed downlink and uplink is possible with either licensed TDD or licensed FDD; [3] Complexity/cost reduction is also applicable to licensed LTE

LAA and LTE-U are designed with fair coexistence as a key principle



Fair Wi-Fi coexistence a key principle in LTE unlicensed design

Extensive over-the-air testing performed in the lab and in the field

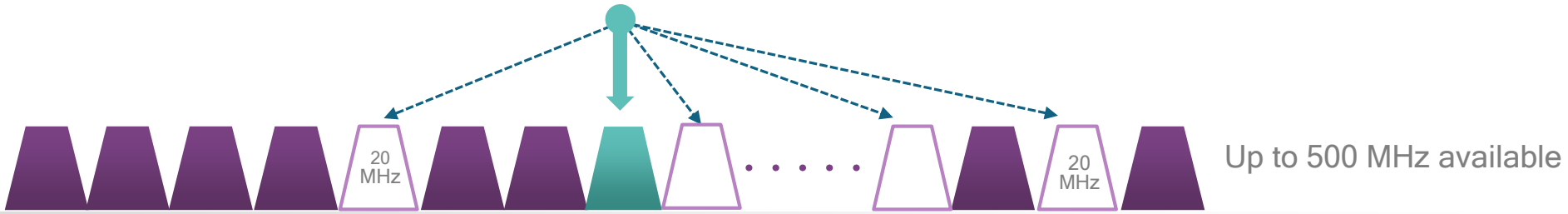


In many cases a better neighbor to Wi-Fi than Wi-Fi itself

[1] Assumptions: 3GPP LAA evaluation model based on TR 36.889 two operators, 4 small-cells per operator per macro cell, outdoor, 40 users on same 20 MHz channel in 5 GHz, both uplink and downlink in 5 GHz, 3GPP Bursty traffic model 3 with 1MB file, LWA using 802.11ac, DL 2x2 MIMO (no MU-MIMO), 24dBm + 3dBi Tx power in 5 GHz for LAA eNB or Wi-Fi AP.

LAA is designed to protect Wi-Fi

Select clear channel: Dynamically avoid Wi-Fi

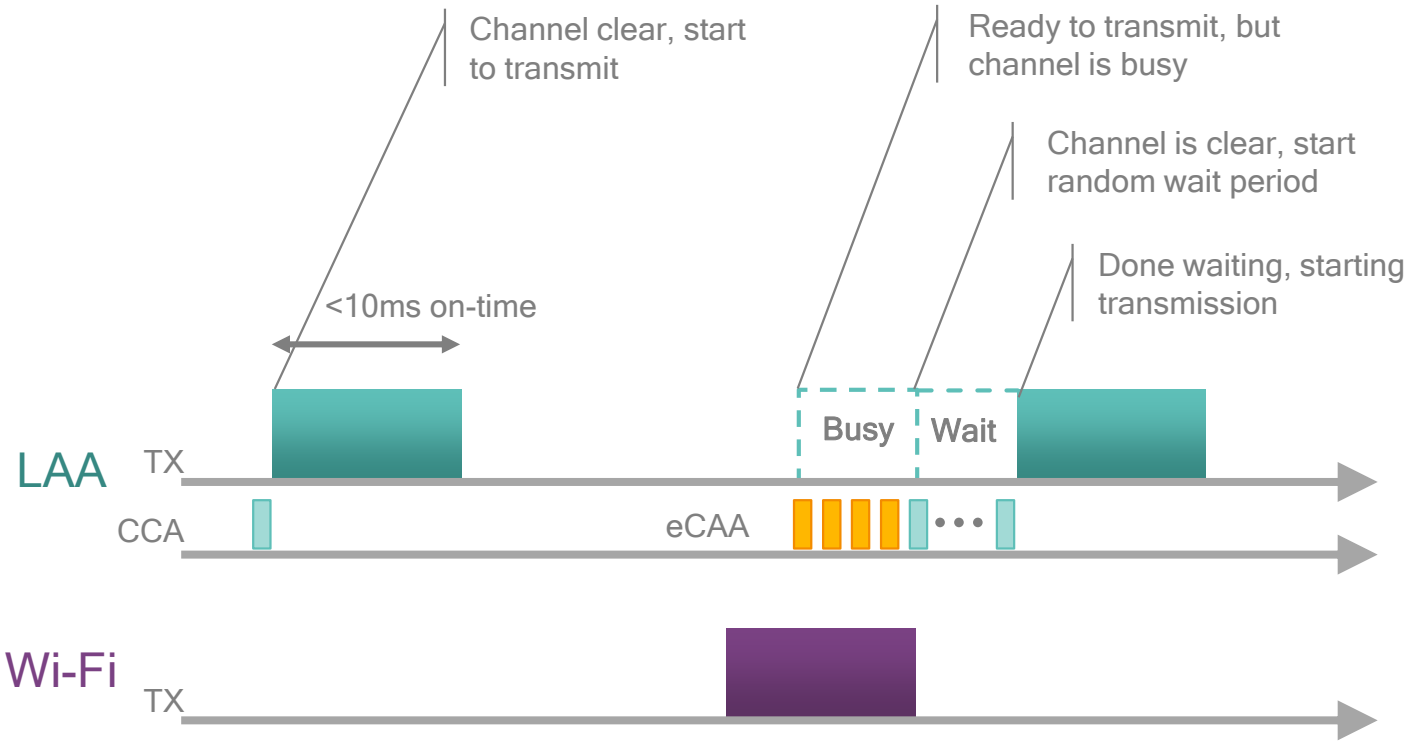


If no clear channel then share fairly: “Listen before talk” (LBT)

Release unlicensed channel at low traffic

LBT ensures fair sharing in unlicensed 5 GHz

LBT is standardized in ETSI EN 301 893



ED – Energy Detect Threshold

Introducing[1] a more sensitive threshold that is common for all technologies when sensing each other.

CCA – Clear channel assessment

If no signal is sensed based on ED threshold, then go ahead with transmission right away.

eCCA – Extended CCA

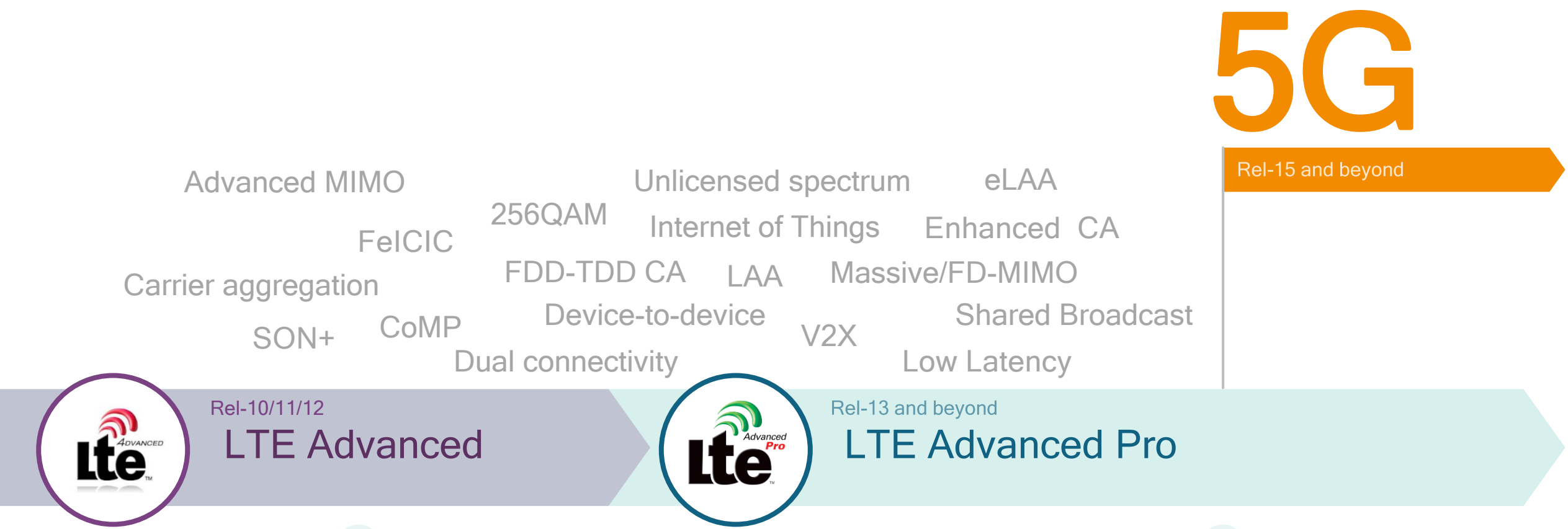
If channel is busy (CCA), then wait for it to become clear. Once it is clear, wait for a random number of additional CCAs indicating that the channel has remained clear before starting transmission.

Designed for fair sharing of 5 GHz	Meets global regulations	Same rule for everyone[1], including Wi-Fi and LTE

1) Proposed in next release of ETSI EN 301 893 with a target release mid 2016.

LAA part of LTE Advanced Pro–a rich roadmap of features

Pushing LTE capabilities towards 5G



Note: Estimated commercial dates. Not all features commercialized at the same time

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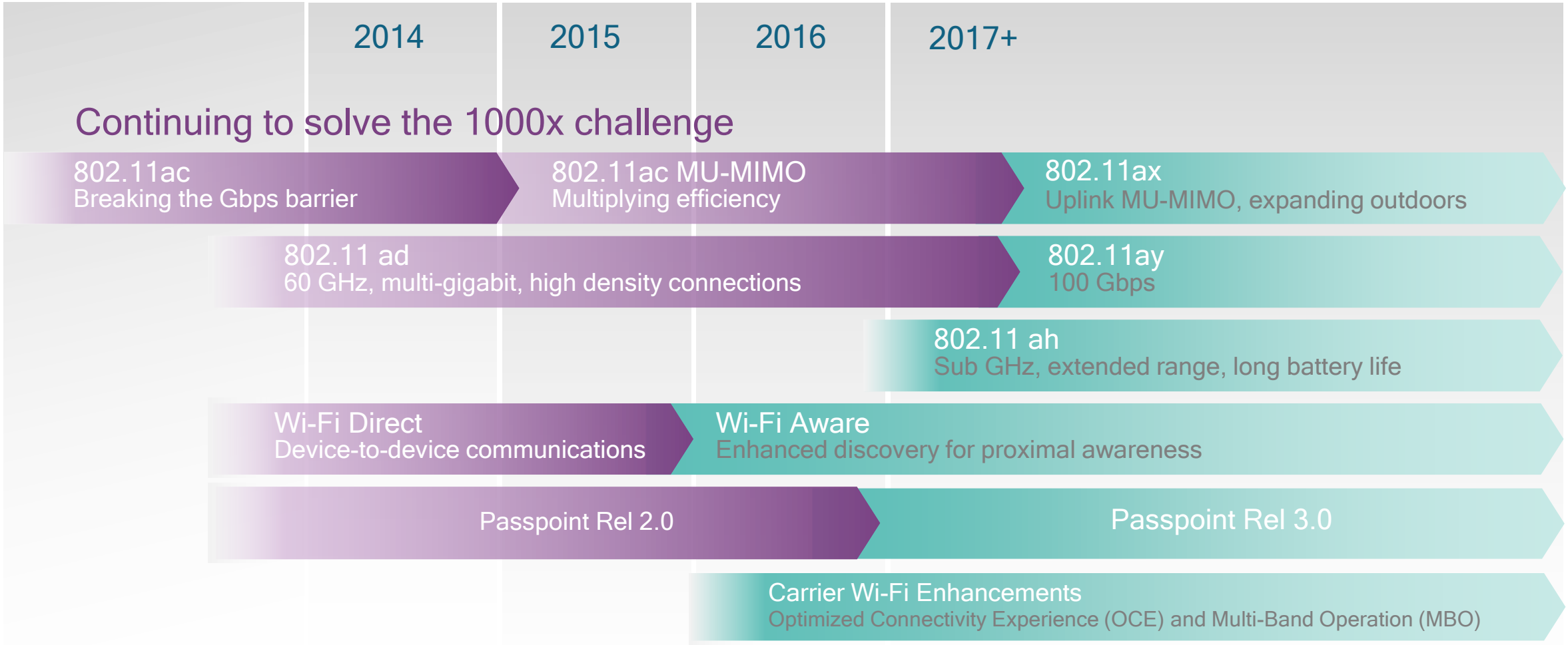
Strong Wi-Fi evolution



Providing the connectivity fabric for everything

Commercial

Note: Estimated commercial dates

802.11ax: Enabling carrier-class deployments

Multi-user efficiency

Higher spectral efficiency – especially in multi-user scenarios

OFDMA, uplink MU-MIMO, 1024QAM & more

Outdoor deployments

Improved outdoor performance

Longer cyclic prefix and longer OFDM symbol duration

Backward compatible

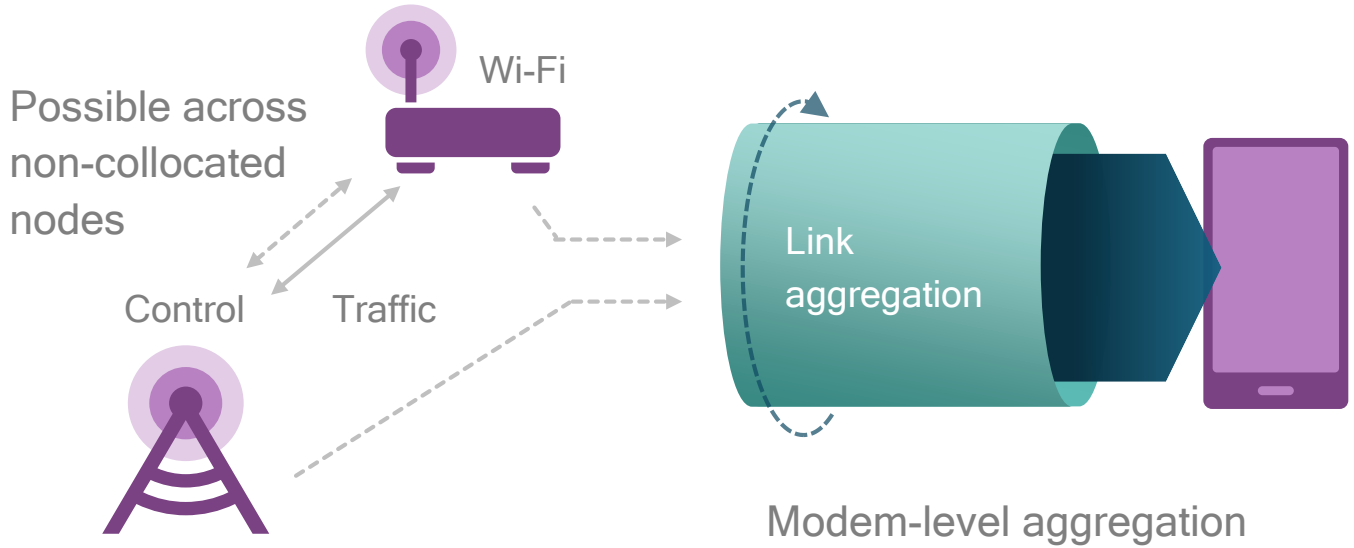
Supports both 2.4 GHz and 5 GHz

Backward compatible with legacy 802.11 (n/ac)

LWA for existing and new carrier Wi-Fi

LTE – Wi-Fi link aggregation part of 3GPP Release 13

Leverages new/existing carrier Wi-Fi
(2.4 & 5 GHz unlicensed spectrum)



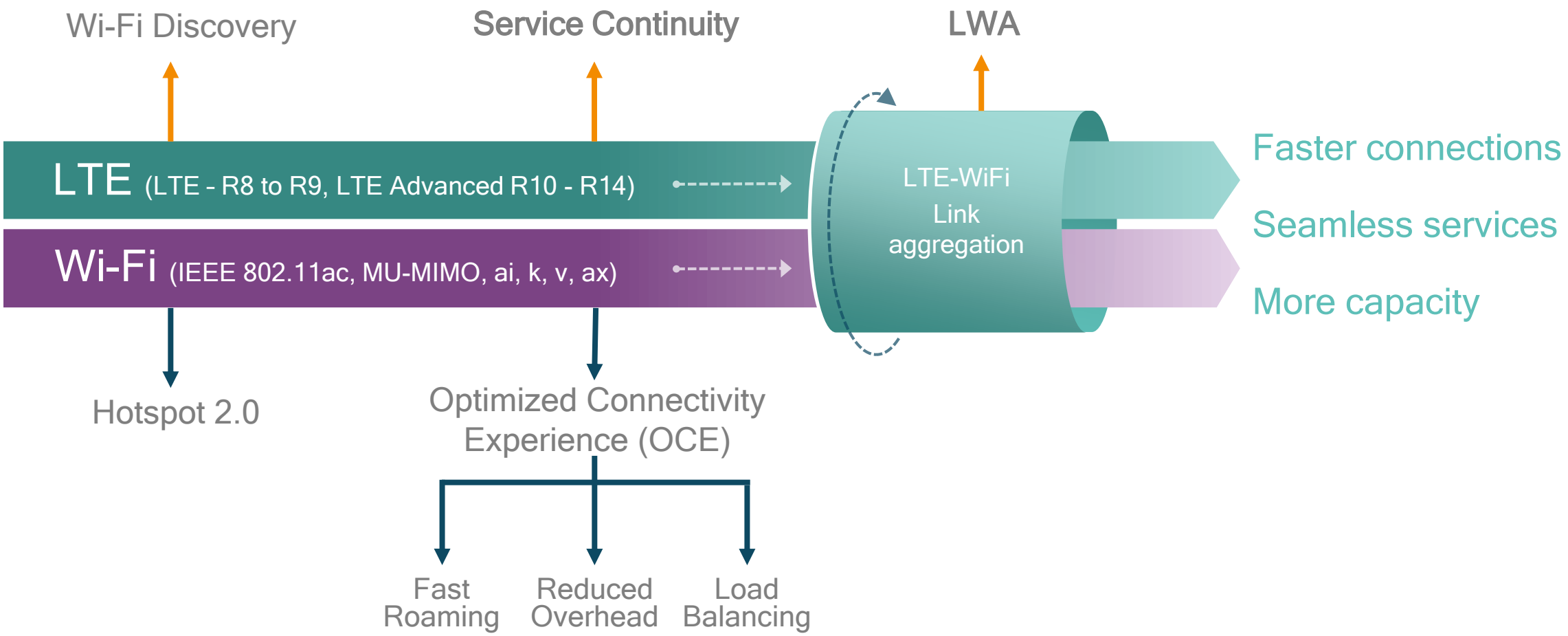
Modem-level aggregation
for superior performance

- **Seamless & robust user experience**
  Licensed anchor for control and mobility
- **Unified network**
  Operator LTE network in full control of Wi-Fi
- **Better performance**
  Simultaneously using both LTE and Wi-Fi links

Notes: Aggregation on modem level (PDCP level), also leveraging dual connectivity defined inR12; Control over X2-like interface needs to be supported by Wi-Fi AP. No change to LTE & WiFi PHY/MAC. No change to core network

Aggregation part of the larger LTE - Carrier Wi-Fi convergence

Also going beyond standards features–driving convergence down to the modem level



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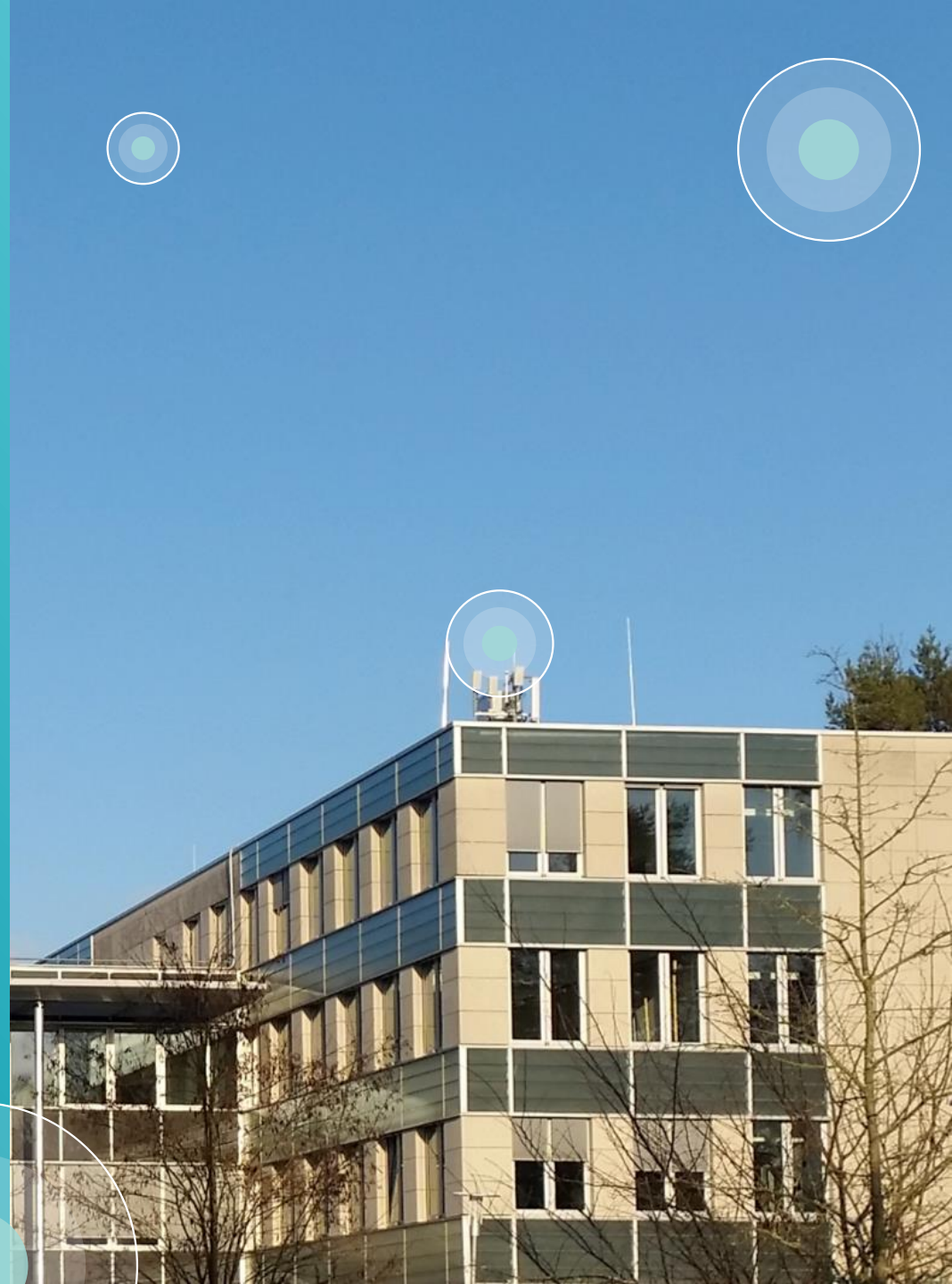

World’s first over-the-air LAA trial during November 2015

Joint effort by Qualcomm Technologies, Inc. with Deutsche Telekom AG

Completed a wide range of test cases

- Indoor and outdoor deployment scenarios
- Different combinations of LAA, LWA and Wi-Fi
- Single and multiple users
- Stationary and mobile users
- Handover between multiple small cells
- Range of radio conditions

Screenshot of live results from trial in Nuremberg, Germany

A combined test cell with LTE, LAA, LWA and Wi-Fi

A big milestone towards commercial deployment

Over-the-air trial demonstrates LAA advantages

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Increased coverage

Demonstrated LAA's extended range and improved performance in 5 GHz compared to Wi-Fi

Increased capacity

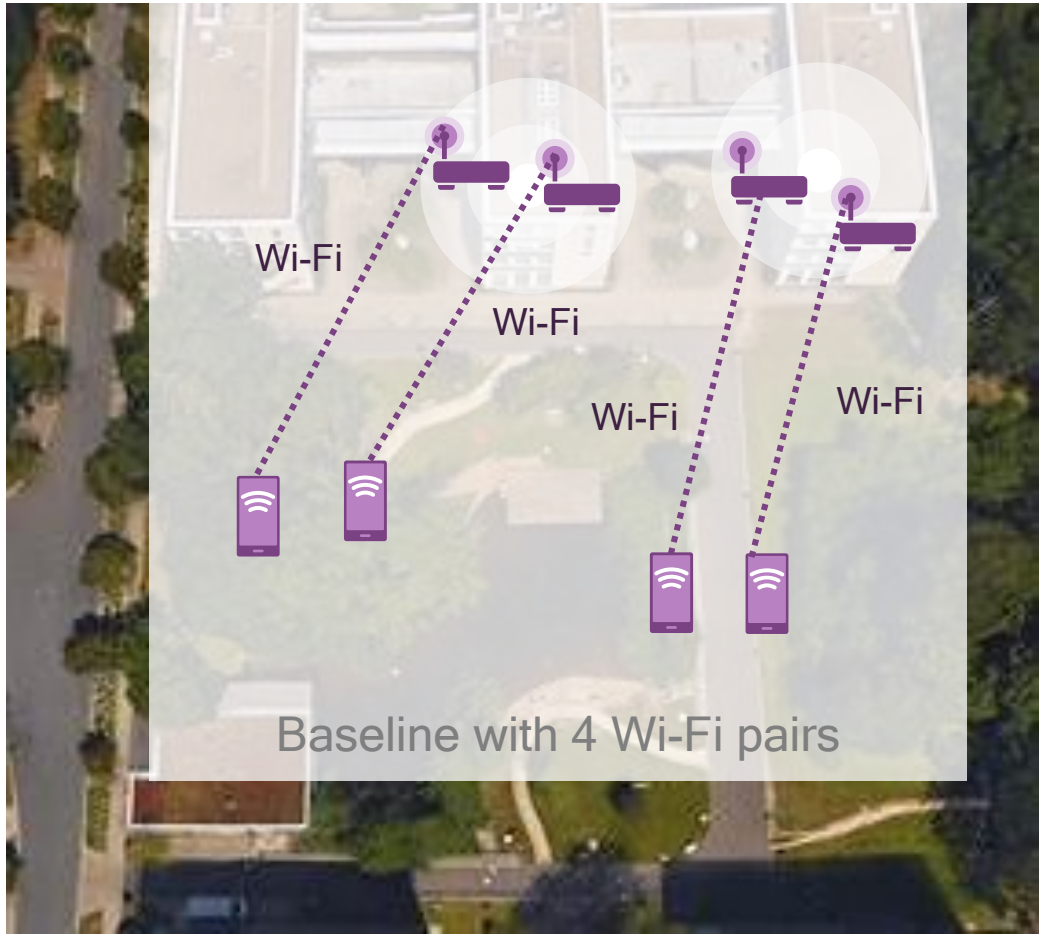
Demonstrated downlink throughput gains over Wi-Fi.

Co-existence that benefits everyone

Demonstrated fair co-existence between LAA, LWA and Wi-Fi with improved performance for everyone sharing the same 5 GHz channel.

LAA benefits everyone sharing the same 5 GHz channel

A better neighbor to Wi-Fi than Wi-Fi itself



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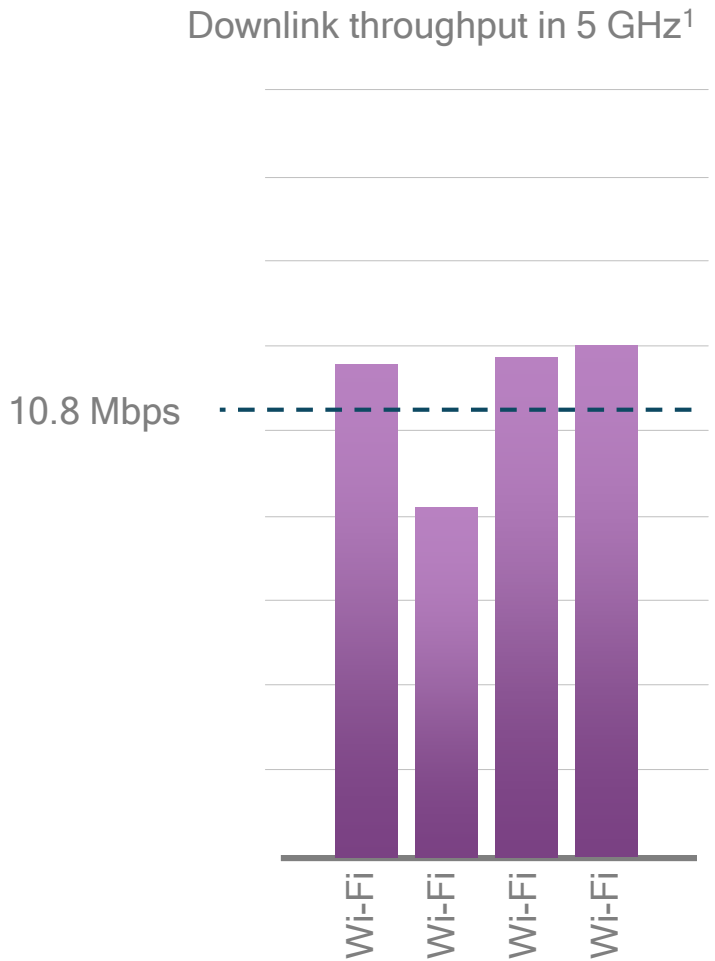
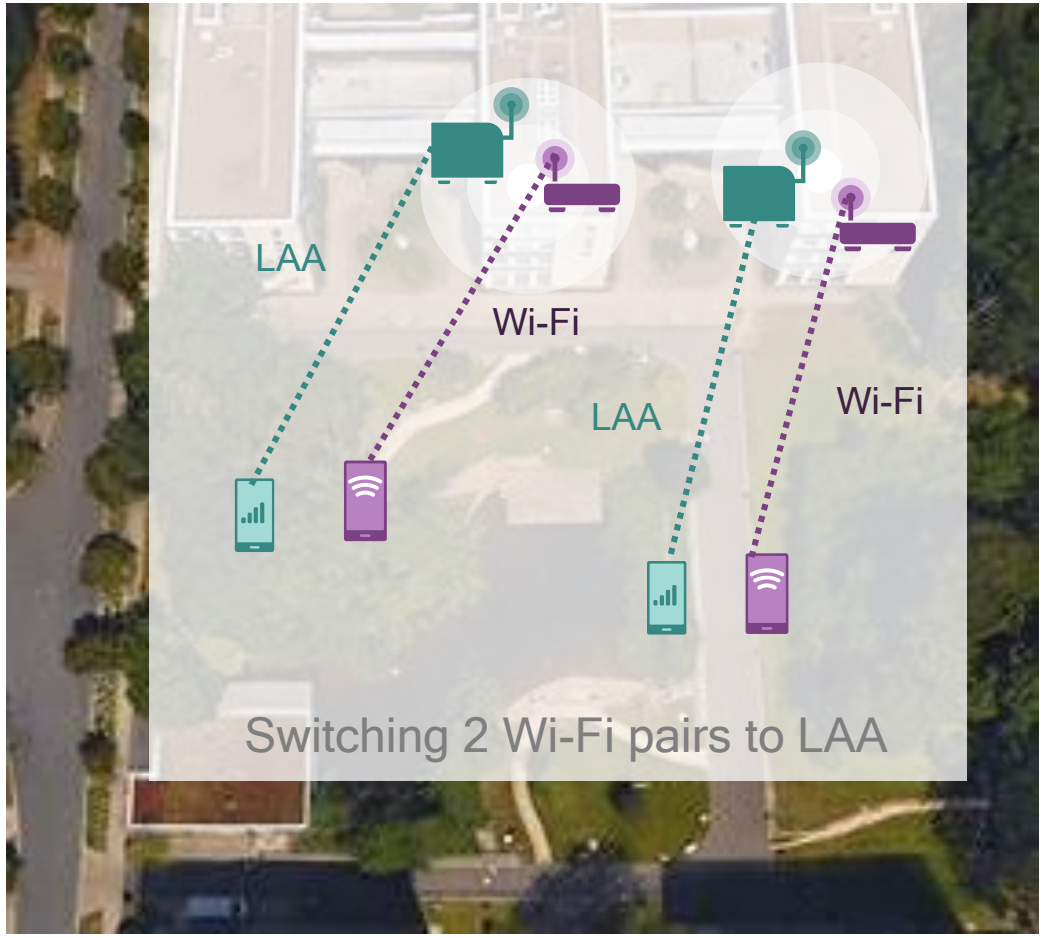


[1] Outdoor, 4 users on 4 different AP/cells, Mix of above and below ED, strong signal level with some interference, LAA based on 3GPP rel. 13; LWA using 802.11ac; LTE on 10 MHz channel in 2600 MHz licensed spectrum with 4W transmit power; the following conditions are identical for LAA and Wi-Fi: 2x2 downlink MIMO, sharing same 20 MHz channel in 5 GHz unlicensed spectrum with 1W transmit power, terminal transmit power 0.2W

LAA benefits everyone sharing the same 5 GHz channel

A better neighbor to Wi-Fi than Wi-Fi itself



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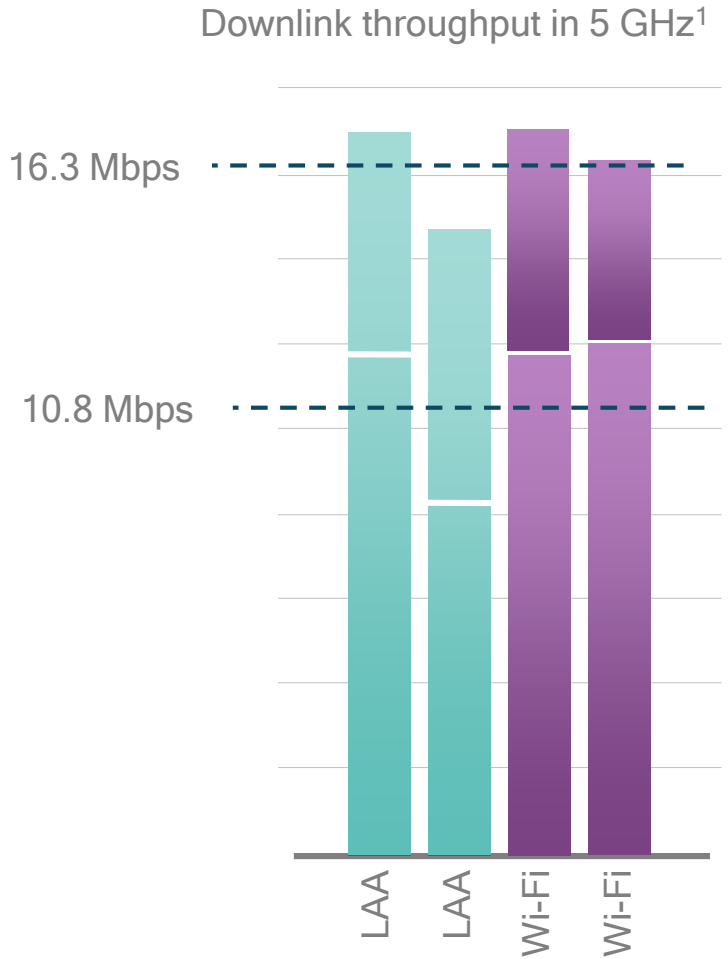

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LAA fairly coexists with Wi-Fi

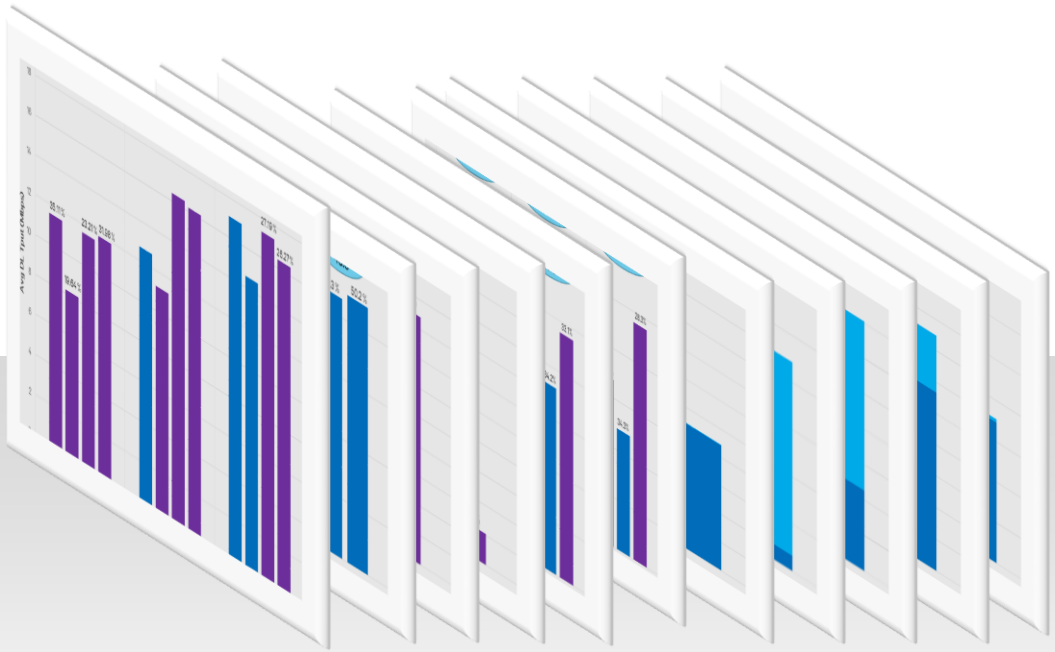
Summary from a large number of test cases over a diverse set of conditions

1

Switching a Wi-Fi AP with a LAA small-cell results in overall increased network capacity and higher throughput for all users.

2

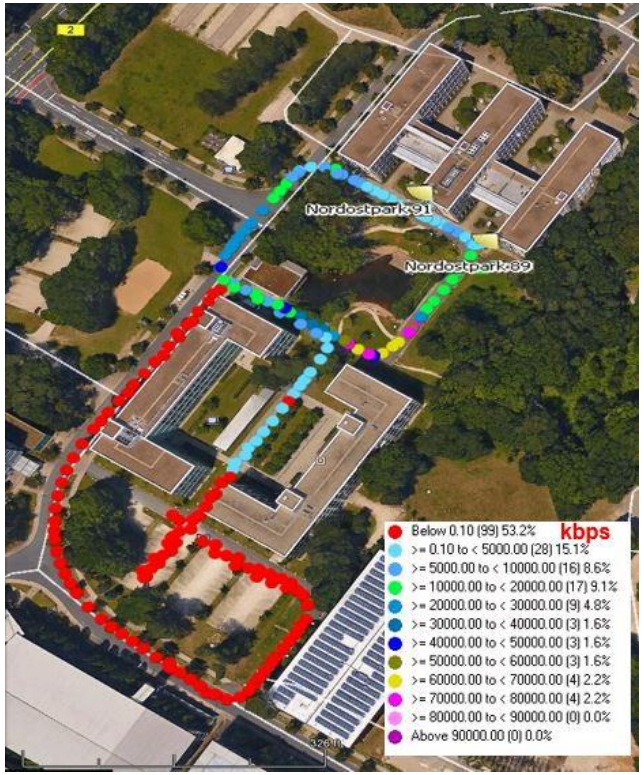
LBT ensures that the channel is shared fairly between the users and LAA is overall a better neighbor to Wi-Fi than Wi-Fi itself.



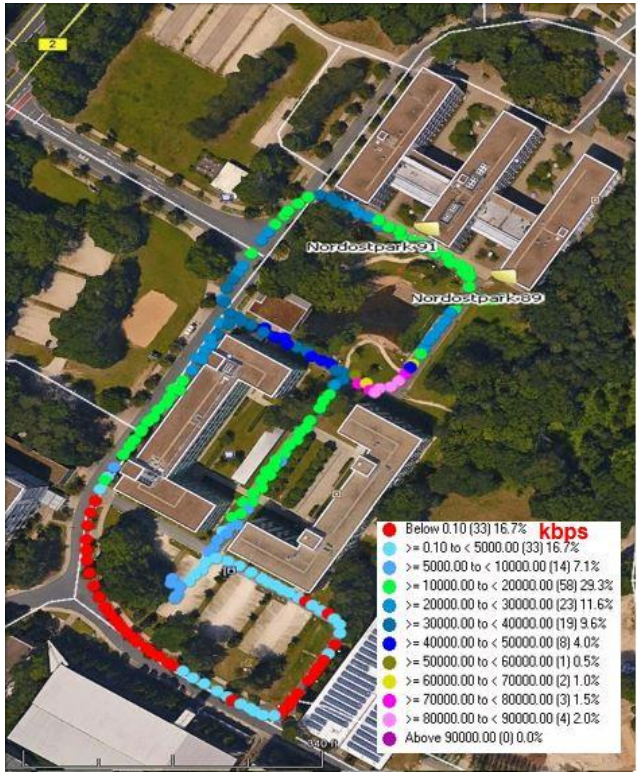
~2X coverage improvement outdoors

Downlink throughput in unlicensed spectrum for each location on test route[1]

LWA (Wi-Fi)



LAA



Coverage[2] in unlicensed

Mbps	Wi-Fi	LAA
		x2.5
>10	24% of route	60% of route
		x1.8
>1	39% of route	71% of route
		X1.7
>0	47% of route	82% of route

[1] Single small cell, LAA based on 3GPP release 13; LWA using 802.11ac; LTE on 10 MHz channel in 2600 MHz licensed spectrum with 4W transmit power; the following conditions are identical for LAA and Wi-Fi: 2x2 downlink MIMO, same 20 MHz channel in 5 GHz unlicensed spectrum with 1W transmit power. terminal transmit power 0.2W, mobility speed 6-8 mph; [2] Based on geo-binned measurements over test route

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MulteFire – LTE-like performance with Wi-Fi-like simplicity

Operating 4G LTE technology solely in unlicensed spectrum, e.g., 5 GHz

LTE-like performance

- Enhanced capacity and range
- Improved mobility, quality-of-experience
- Hyper-dense, self-organizing deployments

Harmoniously coexist with Wi-Fi, LTE-U/LAA

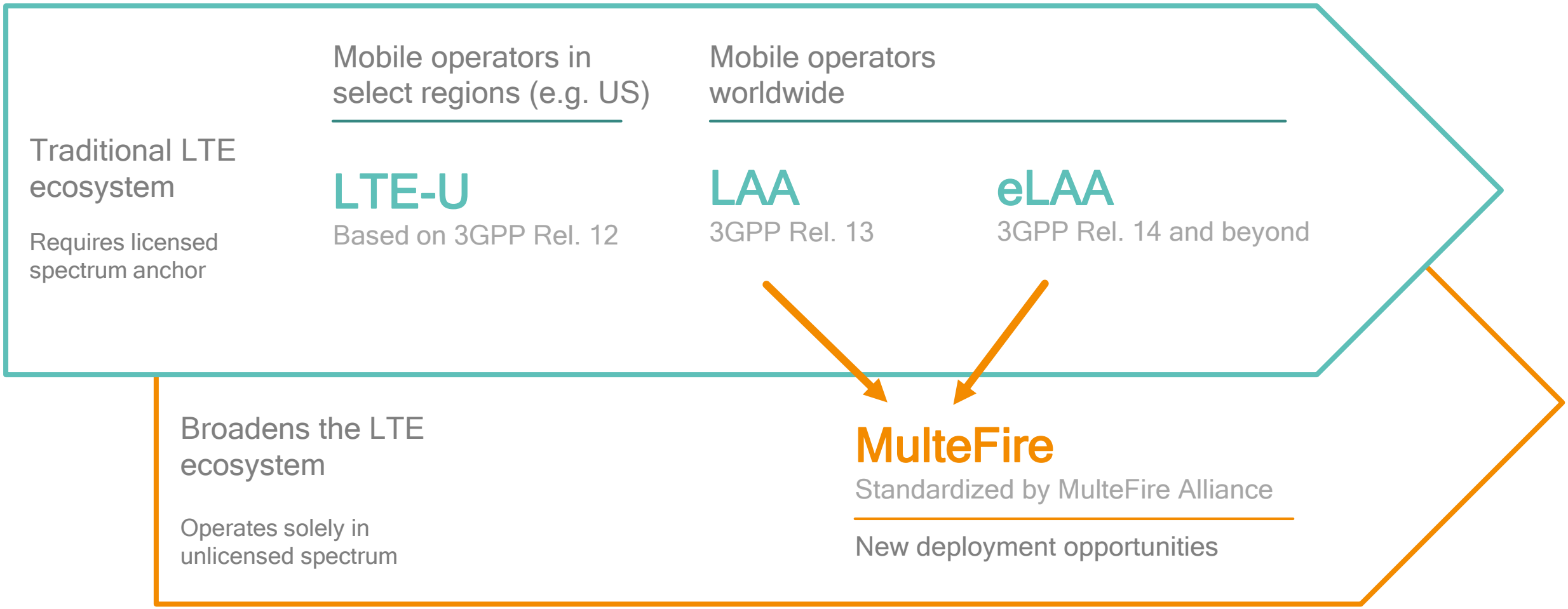
Wi-Fi-like simplicity

- Operates in unlicensed spectrum
- Leaner, self-contained network architecture
- Suitable for neutral host deployments

Broadens LTE ecosystem to new deployment opportunities

MulteFire is based on 3GPP standards

Similar performance and same coexistence as LAA in unlicensed



MulteFire offers benefits across the ecosystem

Deployed by ISPs, CableCos, Enterprises, Venue owners, Mobile Operators,…

Simple deployments

Self-contained architecture with self-organizing functionality suitable for high-capacity dense deployments

End-user experience

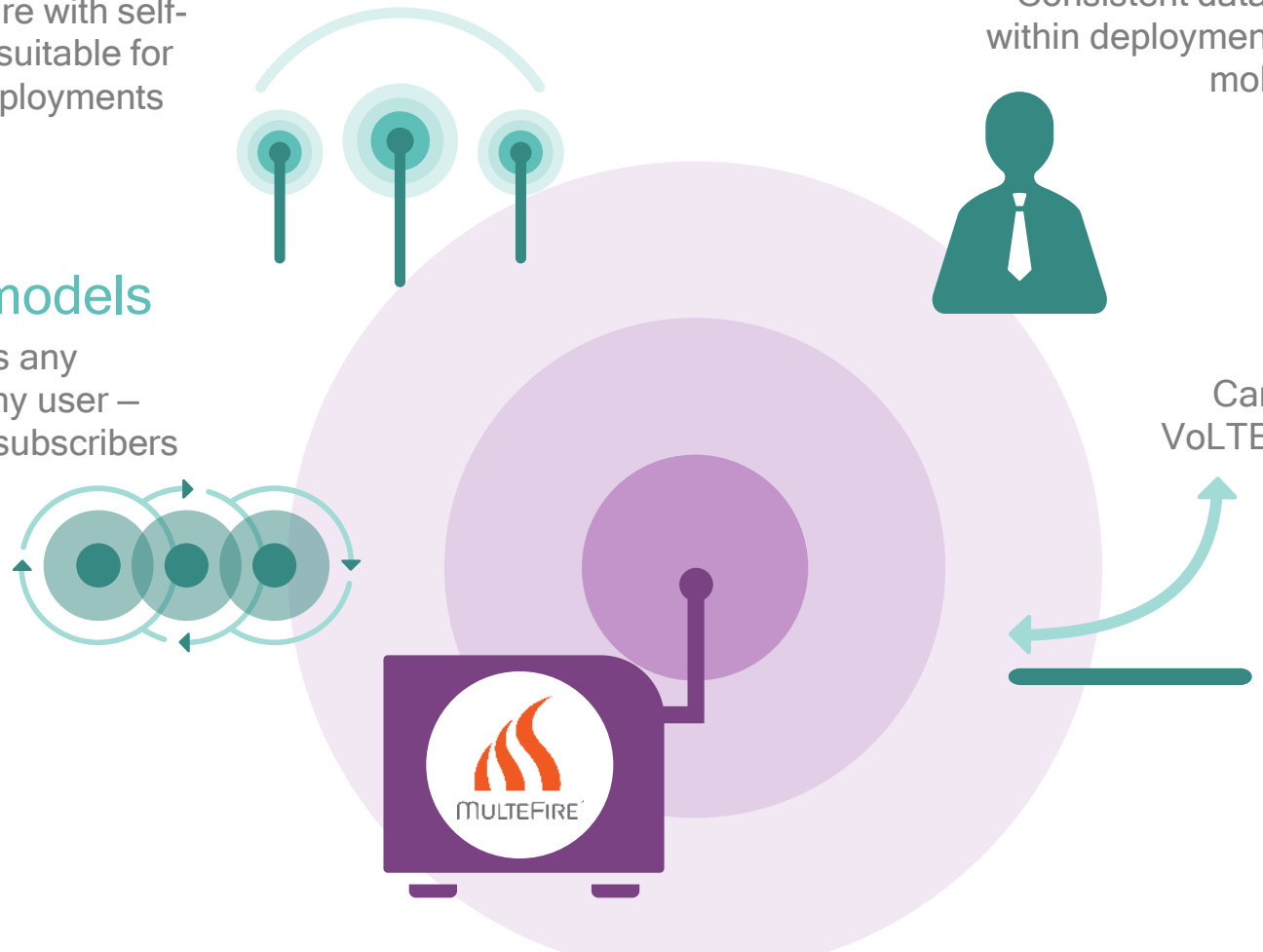
Consistent data rates, seamless mobility within deployments and service continuity to mobile networks

New business models

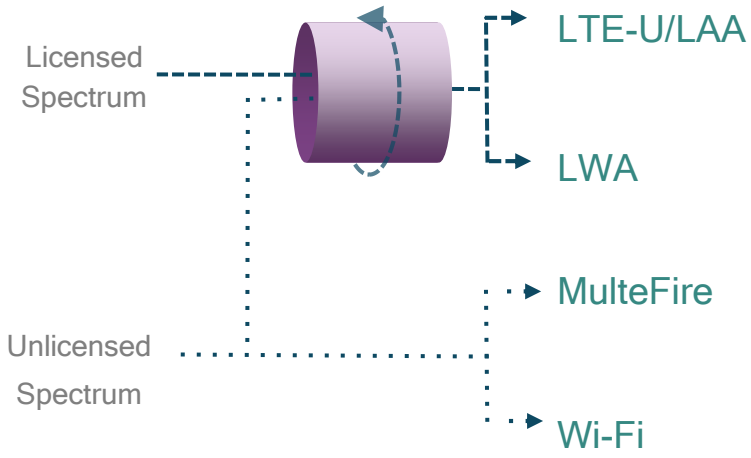
Neutral host enables any deployments to serve any user – including mobile operator subscribers

Strong LTE roadmap

Can use existing LTE features such as VoLTE and Broadcast and is aligned with the 3GPP evolution



Summary



Multiple solutions will coexists in unlicensed

Different solutions for different deployment scenarios with converged LTE – Wi-Fi solutions.

Fair coexistence between LTE and Wi-Fi is verified

LTE in unlicensed is designed to coexist fairly with Wi-Fi as shown in comprehensive over-the-air trials.

LAA technology paves the way for MulteFire

MulteFire is based on LAA with similar performance advantages. Combined with Wi-Fi like deployment simplicity, it can offer the best of both worlds.

Thank you

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